Aerial survey of kangaroos in South Australia 1978–1998: a brief report focusing on methodology

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ABSTRACT

Twenty-one surveys have been conducted using a Cessna 182 in the pastoral zone of South Australia, covering the twenty year period 1978 to 1998, flying the same transects and using the same method. Considerable attention has been given to observer training and the turnover rate of observers has been low. The same pilot has flown all surveys. The pastoral zone is bounded in the north and west by a dingo-proof fence. Large lakes and areas of terrain above 2 000 ft elevation (notably the Flinders Ranges) were excluded from the survey, leaving a surveyed area of approximately 207 000 km². Surveys are conducted each year in July/August, with morning and afternoon survey sessions. Transects run east/west and are 15 nautical miles (28 km) apart. The method has followed what has become the standard for fixed-wing surveys: a height of 250 ft (76 m) above ground (AGL), a ground speed of 100 knots (185 km h^{-1}), 5 km unit lengths (97 sec.) with a 7 sec. pause between each and animals counted in 200 m wide strips each side of the aircraft, demarcated by streamers attached to the wing struts. A radar altimeter is used to maintain height above the terrain and, since 1989, a global positioning system has been used to ensure adherence to the transect and to maintain the required groundspeed. Red kangaroos, western grey kangaroos, common wallaroos, emus and goats are counted and other macro fauna noted (camels, horses, dingoes, ostriches, etc.). Standard correction factors have been applied throughout, except that, in the present paper, the data are recalculated to reflect the outcomes of this workshop concerning a move to modified correction factors. The results have highlighted the responsiveness of kangaroo populations to rainfall and pasture availability. There has been a statistically significant long-term trend towards higher numbers of western grey kangaroos in the study area, and a similar trend in reds since the end of the 1982/1983 drought. Over the 20 years, however, there has been no statistically significant trend to either higher or lower numbers of red kangaroos. Some analyses of the data obtained by aerial survey have already been presented and, in due course, further analyses will be presented elsewhere. Importantly, the results provide a useful demonstration that long-term harvesting can be carried out without detriment to the populations.

INTRODUCTION

Although aerial survey of kangaroos has been conducted in New South Wales since 1975, the South Australian survey is the longest running using the same format and method. The purpose of this paper is to record and discuss some of the considerations about methods which have dictated our conduct of the surveys each year. Although not presented at the workshop, this paper has been added to the written proceedings to achieve a more complete overview of the topic.

HISTORY AND OUTPUTS

The origin of the South Australian kangaroo surveys was at the 1977 workshop on aerial survey (Anon. 1979), sponsored by the (then) Australian National Parks and Wildlife Service (ANPWS). Bob Lyons and Laurie Delroy of South Australian National Parks and Wildlife Service approached Graeme Caughley and Gordon Grigg at that meeting to ask if they would be willing to conduct a survey of kangaroos in the South Australian pastoral zone in 1978. Laurie Delroy wanted to put the harvest of kangaroos in that state on to a more quantitative basis, and had gained the support of Bob Lyons, then the Director of the Service. Graeme Caughley had been conducting experimental work on aerial survey of kangaroo populations (Caughley *et al.* 1976), determining appropriate correction factors and focusing on other aspects of methodology. He had also been conducting surveys in New South Wales and Queensland firstly with George Wilson as pilot and later from mid-1975 with Gordon Grigg. There was agreement to conduct the survey in 1978 and then to repeat it in 1979. Since then it has become a regular event, important now in the context of setting the annual quota for harvests of red and grey kangaroos in the year immediately following the conduct of the survey. Lyn Beard joined the team as an observer in 1979 and, in 1980, Graeme Caughley went to CSIRO leaving Grigg and Beard to manage the team and to continue the annual surveys. Graeme Caughley

continued to take an interest in the work until his death in February 1994. Grigg and Beard moved from the University of Sydney to the University of Queensland in 1989 and conducted the work from there. It may be worth recording that Delroy and Lyons had indicated that they were particularly comfortable about having a survey team come from out of state to conduct the work, because there could be no suggestion of accusations about local bias.

In the first three years the survey was completed in two separate trips from Sydney in August and September/October. Since 1980, we have found it more convenient to conduct the survey in a single time period in late July and early August. A scheduled break in the middle, plus breaks which occur opportunistically as a result of delays caused by bad weather, ensure that the crew remains fresh.

The data have been the focus of a continuing study on the population ecology of kangaroos that was funded initially by ANPWS (see publication list below). We have also published several descriptive papers, including information about goats and emus (see publication list below). Additionally, Peter Alexander and Stuart Cairns have conducted ground surveys of kangaroos on a number of properties within the pastoral zone, adding some ground truthing element. We anticipate a major review and further work on the population ecology summarizing data in the future, perhaps after 25 years (2003).

SURVEY DESIGN

In designing the initial survey, we saw no need to depart from what had by then become routine east/west orientation of the transects, because this gives the best view for the observers. Further, if the pilot plans a session with care, it is likely that easterly flights first thing in the morning or westerly flights last thing in the evening can be avoided. But should the sampling be random or systematic? That is, should we choose transects at random, or make them standard distances apart, providing an even cover? Caughley's opinion, as we devised the first survey, was that the benefits of randomization did not outweigh the logistic benefits derived by spacing transects at regular intervals (Caughley 1977). Accordingly, to achieve a reasonable sampling intensity while keeping costs and survey length within reasonable limits, we chose transects 15 nautical miles (28 km) apart, spaced evenly in relation to lines of latitude (that is, at 7½', 22½', 37½' and 52½') in each of the degree blocks (Fig. 1) (Caughley and Grigg 1981).

At that stage there was no expectation that surveys would become an annual event, but the decision to choose systematic rather than random sampling was probably a good one, as it happened, because surveys from year to year are comparable in that the same terrain is sampled each year. This should enhance the capacity of the surveys to detect trends. Another factor is that, had we chosen a random design in that first year, each year would have become a new logistical nightmare in planning to fly a new set of transects chosen randomly. The Flinders Ranges lay within the survey area and it was deemed too difficult to survey the steep terrain, so all of the survey area higher than the 2 000 ft contour was defined as being outside the survey area. Also excluded were the many large salt lakes such as Lake Frome, Lake Torrens, Lake Gairdner and Lake Harris because these did not provide suitable habitat for kangaroos. Flight sessions were dictated by the availability of fuel and accommodation and the wish to minimize positioning flights. Operations became based progressively on the towns of Mildura, Renmark (sometimes Waikerie), Broken Hill, Leigh Creek, Port Augusta, Tarcoola (Kingoonya for the first few years) and Coober Pedy.

OPERATIONAL ASPECTS

Flight planning

In recent years, the formal requirements to lodge flight plans have been relaxed considerably, only a Flight Note being required to be left with colleagues or a responsible person who would then be expected to alert officials in the event of the aircraft failing to return. We have preferred to continue to lodge a formal flight plan with Air Services Australia, giving good details of the survey area and nominating a search and rescue time (SARTIME). Sartimes, which have to be cancelled by radio or telephone to avoid an uncertainty and then a search phase being declared, are chosen to be shortly after the expected return from a session.

Weather, wind and time of survey

It is easy to get weather forecast details from Air Services Australia. There are two aspects to consideration of the weather for aerial survey, first of all those of safety for the aircraft and crew and, secondly, the suitability of light levels for viewing. A good cloud base at 3 000 ft, for example, while being perfectly safe from an aeronautical point of view might produce insufficient light, or light that was too flat to give the observers a

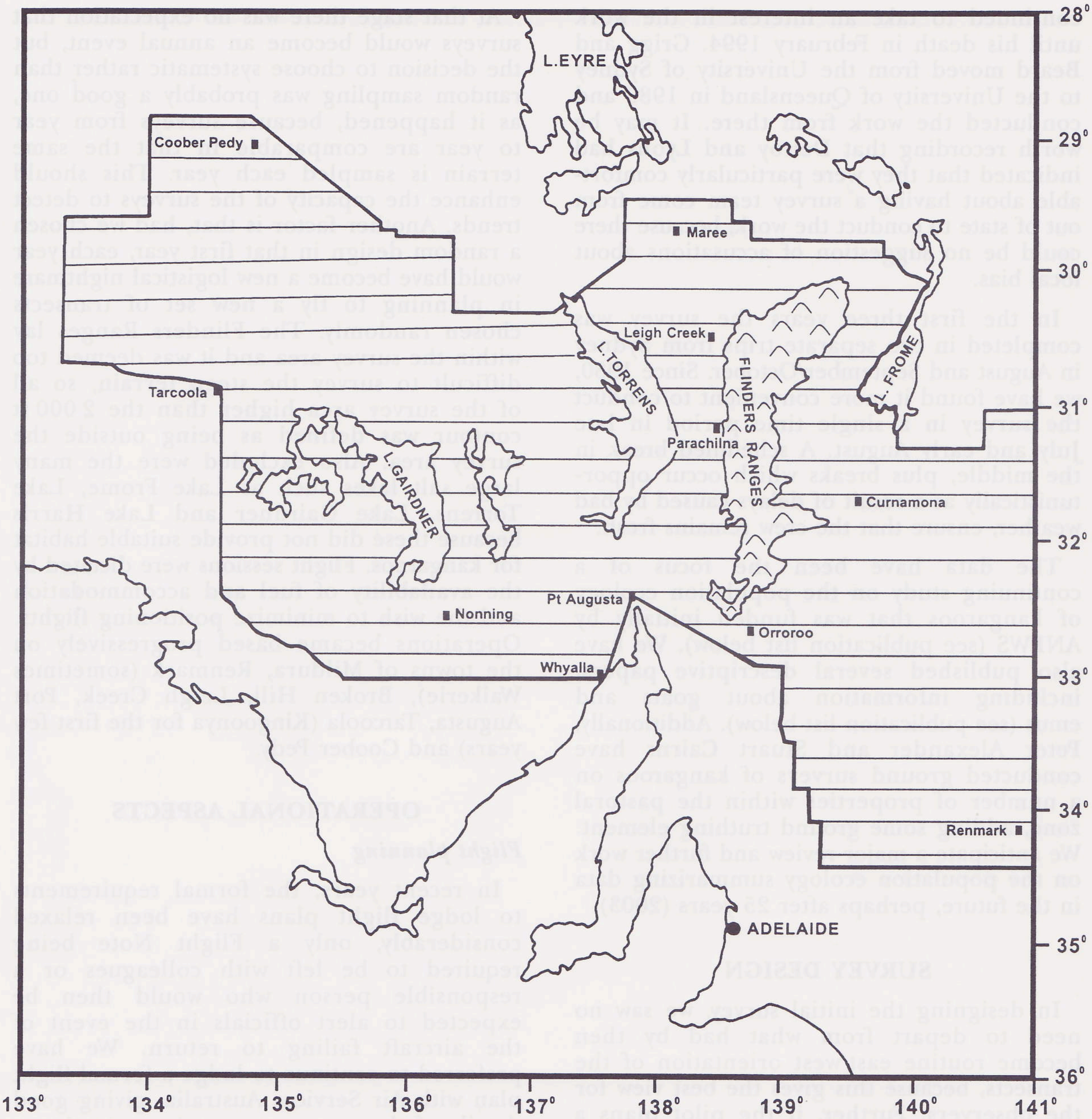

Figure 1. The South Australian pastoral zone showing flight lines for kangaroo surveys. Flight lines in the far south-west and far south-east were surveyed infrequently. The pastoral zone is bounded in the north and west by a dingo-proof fence.

good view. Sometimes we abandoned sessions when the light deteriorated or was judged inadequate. Wind strength and direction also has a large bearing on suitability of weather for aerial survey work. Strong winds promote turbulence near the ground, particularly as the day advances and convection from the warming surface picks up. Also, the requirement to fly so as to achieve a ground speed of 100 knots imposes limitations. A Cessna 182 cannot maintain a ground speed of 100 knots into a 30 knot head wind, and although flying downwind at 70 knots in such a wind puts the aircraft above the stalling speed, this is not recommended in gusty or turbulent conditions. Another consideration relates to cross winds. In a strong cross wind, the strip passes the observer's eyes at an angle, which must be accommodated for by the observer. In such conditions there is almost always turbulence as well, and gusting conditions, so that the position of the demarcated strip is constantly changing with the yawing of the aircraft.

Surveys early and late in the day, when the kangaroos are less likely to be seeking shade under bushes, are accepted as the norm

for aerial surveys. Air temperatures and the suitability of the light for viewing are both relevant to the choice of survey times and lengths of sessions. Considerations about suitability of the light mitigate against starting too early or finishing too late. There is little value in planning a departure time which, when transport flight time is added, puts the crew at the start of the first transect 15 minutes before the sun rises, because the lighting may be too flat. As the sun rises, its low angle may produce very contrasting shadows into which the animals disappear. Best viewing usually occurs, therefore, when the sun is at a reasonable angle above the horizon, approximately 15–20 minutes after sunrise or before sunset. As for ambient temperatures, more of the day is available for counting at higher latitudes where air temperatures are lower. In South Australia, once kangaroos lie down after their early morning foraging activities they usually do so in the sun on the sheltered side of bushes and are clearly visible to at least one of the observers. Hence there is little problem in extending the survey sessions towards the middle of the day. Survey sessions in Queensland, however, with much warmer air temperatures, have to be shorter and timed to avoid the heat of the middle of the day. We once attempted aerial surveys in summer and this reinforced the importance of conducting surveys in winter when air temperatures are lower and kangaroos are much more likely to be out and visible during daylight.

Maintenance of height and speed

With the advent of the Global Positioning System (GPS), it has become straight forward to fly the planned transect quite accurately. A GPS also provides a continuous readout of ground speed, so air speed can be adjusted to maintain 100 knots. In practice it is really quite easy to maintain this plus or minus about 1 knot, with careful trimming of the aircraft, unless the wind speed is variable, or in the case of "profile flying", which provides more of a challenge (see below). The maintenance of height is very important (Caughley *et al.* 1976) and is best undertaken with reference to a radar altimeter. In the early days we used one, then lost access to it and relied on the pilot's judgement in consultation with experienced observers. On several occasions we took the opportunity to assess this, with the pilot turning the radar altimeter off, climbing and then descending to a judged 250 ft and then turning the radar altimeter back on. These comparisons built our confidence in the ability of an experienced crew to learn to judge height. In the absence of a radar altimeter, one training aide is to note the pressure altimeter reading during the takeoff roll, level out at 250 ft, and gain familiarity with flight at that height (try this only in flat country!). Nevertheless, we strongly urge that the use of a radar altimeter should become standard practice in all kangaroo surveys. It is worth noting that one's perception of height above the ground depends upon ground speed. This means that, if maintaining ground speed with reference to a GPS, the judgement of height above the ground becomes much easier.

Breaks between and during transects

A typical survey session comprises 100–120 individual units, often broken into four lines, two to the east and two to the west. Our experience is that a trained observer (Beard 1999) can maintain concentration comparatively easily for 25–30 units without any breaks beyond the 7 sec. between units during which they record their data. Under these conditions they get a break of 6–8 min between transects while the aircraft is being positioned from the end of one to the start of the next. Sometimes a session comprises two long lines, 50–60 units out and the same number back. In such a session, we have found it prudent to break the long lines like these at the half way point and fly a couple of orbits to give the opportunity for observers to have a break. If there is the luxury of three calibrated observers, the work can be shared so that observers can be counting two on and one off line by line, with the observers in the rear swapping seats as required. Folklore (Graeme Caughley) says that, whereas a pilot can burn out two calibrated observers, three calibrated observers can burnout a pilot. We suspect there may be some truth in that. Whatever, the work requires considerable concentration for both pilot and observers and we have found that it pays for observers to take opportunities to rest whenever they can including during the break between the sessions each day and to get plenty of sleep after a good evening meal.

Hazards

Flying at 250 ft above ground level exposes the aircraft and its occupants to potential risks from power transmission lines, microwave and other towers, and birds. Flight below 500 ft requires an endorsement from Air Services Australia, which is gained only after a period of special training directed at safe operation of an aircraft at low levels. Many of the towers, radio masts and transmission lines

are marked on charts but new obstructions appear year by year and continued vigilance by the pilot is necessary. An additional hazard is posed by rising terrain, particularly with a following wind. Many of the aeronautical implications of low level flight are dealt with in Grigg (1979).

Profile flying

The necessity to maintain a constant height above ground dictates that in hilly terrain the pilot should operate the aircraft so that the flight path replicates the profile of the hills being traversed. While this can be thoroughly entertaining for the crew, it does increase the likelihood of air-sickness and the rapid changes in power setting promote increased engine wear. Accordingly, experienced observers have learnt to compensate for changes in height (= changes in transect width) while the pilot makes some compromises and smoothes the profile

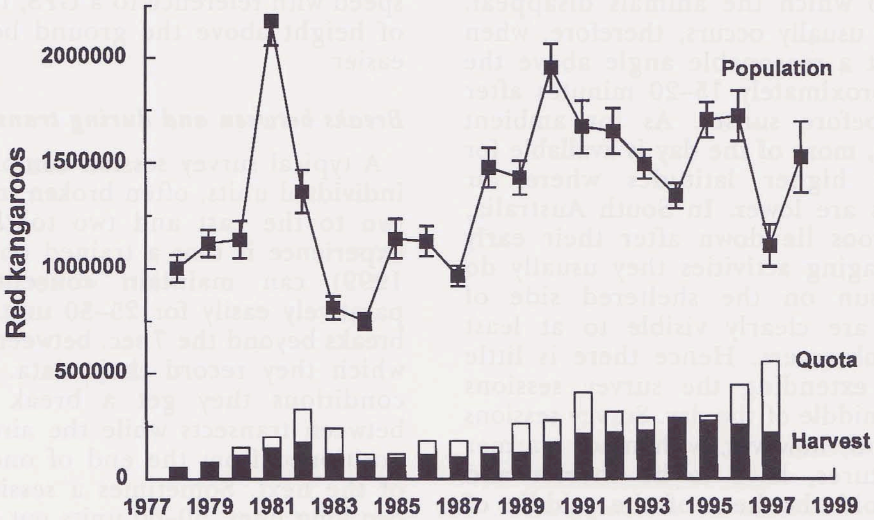

Figure 2. Trends in the numbers of red kangaroos (± s.e.) in the South Australian pastoral zone during 1978 and 1998. Correction factors of 2.29–2.53, depending upon the habitat classification, have been applied to the raw number counted in each aerial survey unit. The annual commercial harvests (solid bars) during this period are shown relative to the annual quotas (solid + open bars) which were first set in 1980. The annual quotas and harvests are for the entire state and include quotas and harvests for areas outside the pastoral zone. However, the vast majority of animals were taken within the pastoral zone.

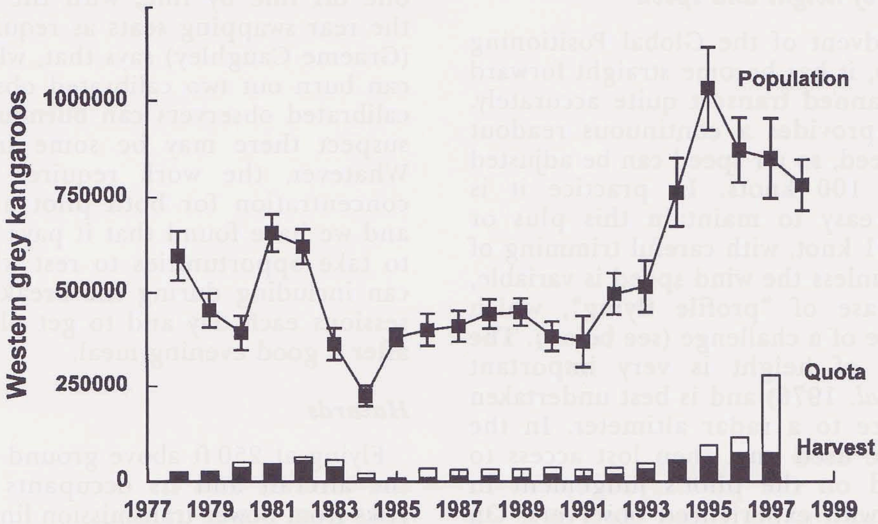

Figure 3. Trends in the numbers of western grey kangaroos (± s.e.) in the South Australian pastoral zone during 1978 and 1998. A correction factor of 4.8 has been applied to the raw number counted in each aerial survey unit. The annual commercial harvests (solid bars) during this period are shown relative to the annual quotas (solid + open bars) which were first set in 1980. The annual quotas and harvests are for the entire state and include quotas and harvests for areas outside the pastoral zone. However, the vast majority of animals were taken within the pastoral zone.

somewhat. Profile flying also challenges the capacity of the pilot to maintain a constant speed and, indeed, ground speed inevitably departs from what is required, due to the limitations of the aircraft. We consider that the reduction in groundspeed during the climb up the face of a ridge is countered by its consequent increase during descent once over the crest and that, while the pilot should attempt to minimize such variations, they probably average out.

RESULTS

Results are not the main focus of this paper, which deals mainly with methodology and some of the practical aspects of survey design and implementation from our experience in South Australia. Indeed, data have been published progressively in various reports and formal publications over the years (see reference list) and data for kangaroos are available on the Internet: http://www.anca.gov.au/plants/wildlife/roo/roobg.htm

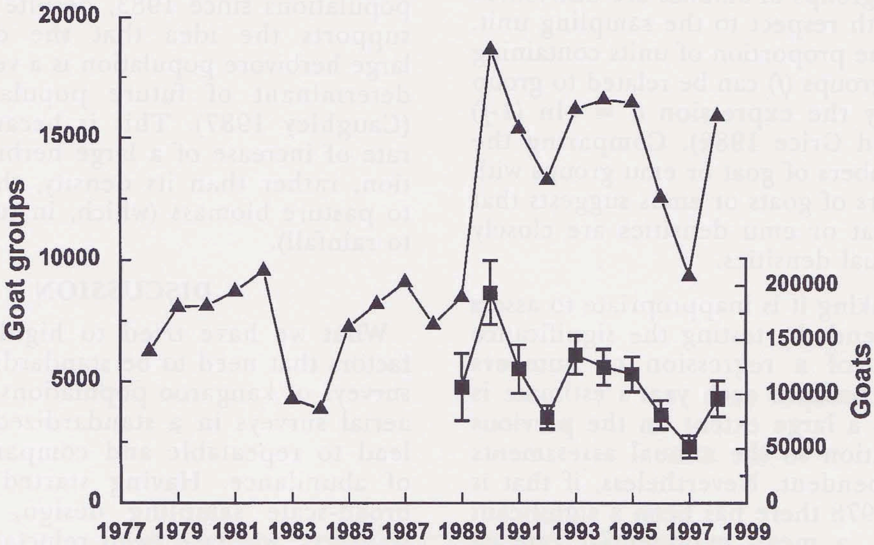

Figure 4. Trends in the numbers of goat groups in the South Australian pastoral zone during 1978 and 1998, based on the presence or absence of goats in aerial survey units (see Pople *et al.* 1996). Numbers of goats have been counted since 1989, allowing an estimate of absolute numbers (± s.e.) for this period. Counts were uncorrected for visibility bias.

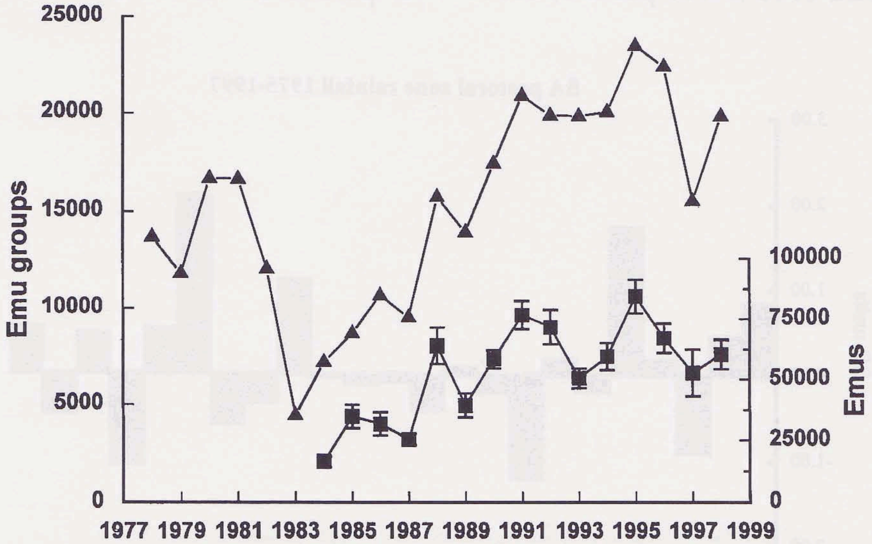

Figure 5. Trends in the numbers of emu groups in the South Australian pastoral zone during 1978 and 1998, based on the presence or absence of emus in aerial survey units. Numbers of emus have been counted since 1984, allowing an estimate of absolute numbers (± s.e.) for this period. Counts have been multiplied by 1.47 to correct for visibility bias (Caughley and Grice 1982).

Nevertheless, for completeness, we include here the pastoral-zone-wide figures updated to show the latest results.

Trends in the numbers of red kangaroos, western grey kangaroos, goats and emus during the period 1978 to 1998 are shown in Figures 2–5. Initially, only the presence and absence of goats and emus were recorded in survey units. However, this still provides an index of goat and emu abundance. The frequency of units in which these animals were recorded can be converted to a density if it is assumed that groups of animals are distributed at random with respect to the sampling unit. Specifically, the proportion of units containing goat or emu groups (f) can be related to group density (d) by the expression $d = -\ln(1-f)$ (Caughley and Grice 1982). Comparing the trends in numbers of goat or emu groups with actual numbers of goats or emus suggests that indices of goat or emu densities are closely related to actual densities.

Strictly speaking it is inappropriate to assess population trends by testing the significance of the slope of a regression of numbers against time, because each year's estimate is dependent to a large extent on the previous year's population so the annual assessments are not independent. Nevertheless, if that is done, since 1978 there has been a significant increase (i.e., a mean exponential rate of increase, $r > 0$) in the numbers of western grey kangaroos ($r = 0.03 \pm 0.01$, $F_{1,19} = 6.91$, $P < 0.05$), goat groups ($r = 0.05 \pm 0.01$, $F_{1,19} = 16.60$, $P < 0.001$) and emu groups ($r = 0.04 \pm 0.01$, $F_{1,19} = 8.92$, $P < 0.01$). For red kangaroos, the mean rate of increase during 1978 and 1998 is also positive, but is marginally non-significant ($r = 0.02 \pm 0.01$, $F_{1,19} = 4.00$, $P \approx 0.06$), with a significant increase since 1982 ($r = 0.03 \pm 0.01$, $F_{1,15} = 7.08$, $P < 0.05$) after the big drought. The pattern of annual rainfall during 1975–97 (Fig. 6) was characterized by a severe drought in 1982/83 and a number of years of well-above average rainfall over the last 10 years. These data await further analysis but, generally, the annual exponential rates of population increase of these herbivores reflect this rainfall pattern (e.g., Cairns and Grigg 1993). Furthermore, the continued climb of these populations since 1983, despite dry periods, supports the idea that the density of a large herbivore population is a very important determinant of future population density (Caughley 1987). This is because it is the rate of increase of a large herbivore population, rather than its density, that is related to pasture biomass (which, in turn, is linked to rainfall).

DISCUSSION

What we have tried to highlight are the factors that need to be standardized in aerial surveys of kangaroo populations. Conducting aerial surveys in a standardized way should lead to repeatable and comparable indices of abundance. Having started out with a broad-scale sampling design, using fixed transects, we have been reluctant to change the format, believing that, ultimately, a knowledge of trends is more valuable for wildlife management than information about absolute numbers. An index of density allows an assessment of population trend and the impact on the trend of harvesting at a particular rate. Other factors, such as

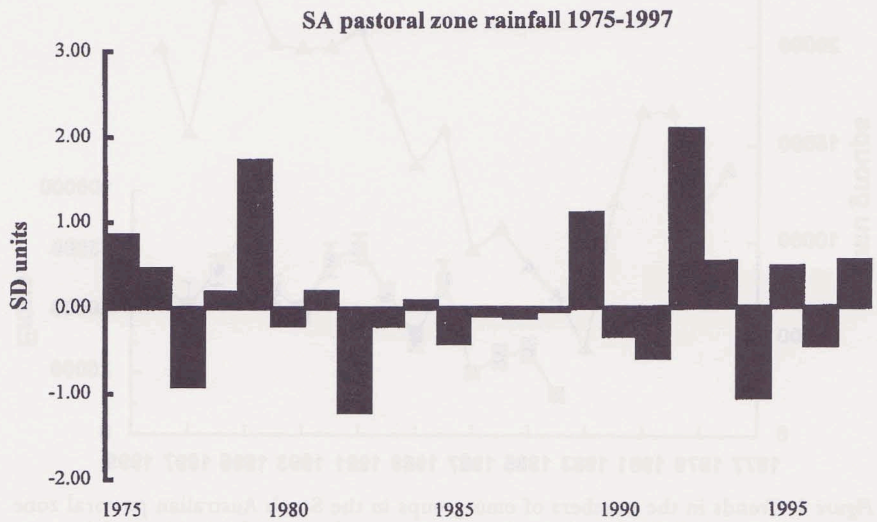

Figure 6. Mean standardized annual rainfall (s.d. units) for the South Australian pastoral zone during 1975 and 1997 based on rainfall recorded at Renmark, Curnamona, Nonning, Tarcoola and Coober Pedy (see Fig. 1).

recent rainfall history, will influence the trend and must therefore be taken into account. Thus, quotas can be fine-tuned. Nevertheless, because harvest quotas are set as a proportion of absolute population size, providing an estimate of absolute numbers is a significant part of the aim of the aerial surveys in South Australia.

Apart from their immediate value in management, regular broad-scale surveys of kangaroos conducted throughout Australia are also providing increasingly long time series of data which are greatly improving our understanding of the population dynamics of several large herbivore species. This is of much more than purely academic interest, because such an understanding is integral to decisions about long term harvesting and land management strategies. This information could not have been obtained within the constraints of a typically pure research programme, where funding is usually restricted to short time frames (≤6 years). Indeed, the compilation and analysis of these datasets of kangaroo population density provides a good example of collaboration and mutualism between government management agencies (Federal and State) and research organizations (universities and CSIRO).

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